Erodibility of Reconsolidated Topsoil and Subsoil Materials used in Highway Construction

Ontario

Ministry of Transportation

Research and Development Branch

Ontario
Ministry of Transportation
Research and Development Branch

Documentation Page

Erodibility of Reconsolidated Topsoil and Subsoil Materials used in Highway Construction

Author(s): G. J. Wall

Date Published: September, 1991

Published by: Research and Development Branch, MTO

Contact Person: Jack Armstrong, Materials Office
(416) 235- 5254

Abstract: This study examines the effects of long term storage of topsoil and the reconsolidation of subsoil on soil erodibility values. The study approach included both the prediction and measurement of soil erodibilites under simulated and natural highway construction conditions.

Of the four components that influence soil erodiblity (i.e. particle sizes, organic matter content, soil permeability and soil structure), it was postulated that the last two would be most impacted by highway construction practices and equipment. When values for these components were varied from minimum to maximum values in the soil erodibility prediction equation for 15 hypothetical soil materials, the resulting change in K-value would usually change a five class erodibilty classification system by a single class.

Field studies suggest that topsoil erodibility is little affected by the topsoil stockpiling procedures employed in normal highway construction. It was further determined that the reconsolidation of subsoil material leads to reduced soil erodibility.

While some highway construction activities would clearly lead to increased soil erodibility, this study shows that the excavation and reconsolidation of compacted subsoil materials in fill situations can lead to reduced soil erodibility.

Comments:

Key Words: Universal Soil Loss Equation USLE, erodibility, erosion

Copyright Status: Crown copyright © 1991 Ministry of Transportation

MAT-91-06

Erodibility of Reconsolidated Topsoil and Subsoil Materials used in Highway Construction

G. J. Wall
G. J. Wall Ltd.

Published by
The Research and Development Branch
Ontario Ministry of Transportation

Published without prejudice as to the application of the findings.
Crown copyright reserved; however, this document may be reproduced for non-commercial purposes with attribution to the Ministry.

For additional copies, contact:
The Editor, Technical Publications
Room 320, Central Building
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8

Telephone: (416) 235-3480
Fax: (416) 235-4872

September 1991

Table of Contents

Executive Summary iv

1/ Introduction 1

2/ Objectives 1

3/ Study Approach 2

4/ Methods 2

4.1/ Soil Erodibility Prediction 2

4.2/ Study Locations 3

4.3/ Field Procedures 4

4.4/ Laboratory Procedures 4

4.5/ Statistical Procedures 4

5/ Results 5

5.1/ Predicted Variation in Soil Erodibility 5

5.2/ Measured Variation in Soil Erodibility 8

5.2.1/ Soil Physical Properties 9

5.2.2/ Runoff Volumes 11

5.2.3/ Soil Loss 12

6/ Summary and Conclusions 15

7/ Study Team 18

Bibliography 19

Appendix A/ Effect of variation of Soil Structure and Permeability Indices on Predicted Soil Erodibility of 15 Soil Materials 20

Appendix B/ Soil Texture of the 15 Soil Materials Studied for Changes in Soil Erodibility ... 25

Appendix C/ Photographs of Field Sampling Locations at Highways 115 and 427 26

Appendix D/ Cumulative Volumes at Highway 115 Site 31

Appendix E/ Cumulative Volumes at Highway 427 Site 36

Appendix F/ Soil Losses from Simulated Rainfall Events 41

List of Tables and Figures

Tables

1/ Predicted variation in soil erodibility (K) of 15 soil textures with variation of permeability and structural indices 6
2/ Predicted K-values for Highway 115 topsoil and subsoil materials 7
3/ Predicted K-values for Highway 427 topsoil and subsoil materials 8
4/ Soil properties of topsoil and subsoil materials at the Highway 115 study site 10
5/ Soil properties of topsoil and subsoil materials at the Highway 427 study site 11
6/ Mean soil losses from simulated rainfall events at Highways 115 and 427 17

Figures

1/ Mean runoff volumes from topsoil treatments at Highway 115 13
2/ Mean runoff volumes from subsoil treatments at Highway 115 13
3/ Mean runoff volumes from topsoil treatments at Highway 427 14
4/ Mean runoff volumes from subsoil treatments at Highway 427 14

Executive Summary

A two-phased approach was developed to study the change in soil erodibility that may occur in native soils under highway construction operations. Specifically, the effect of long term storage of topsoil materials and the effect of reconsolidation of subsoil (cut vs fill material) on soil erodibility values were evaluated. The study approach included both the prediction and measurement of soil erodibilities under simulated and natural highway construction conditions.

Soil erodibility (K-values) may be computed from a combination of soil particle size measurements, organic matter, soil permeability and soil structure indices. A first approximation of K-values may be obtained from the soil particle size and organic matter data. It was postulated that the soil permeability and structure values would be most impacted by highway construction equipment and practices.

The soil erodibility prediction equation was used to predict changes in soil erodibility for 15 hypothetical soil materials when the permeability and structural input data were varied from minimum to maximum values. Variation of K-values differed by soil texture, with high clay soils > sandy soils > silty soils. While variation was often large, the resulting change of K-value would usually change a five class soil erodibility classification (slight to very severe) by a single class.

Measurements of runoff and soil losses were taken, from study plots on highway construction locations to establish the relative erodibility of soil stockpiled for top dressing or reconsolidated subsoil materials. The results suggest that topsoil erodibility is little affected by the topsoil stockpiling procedures at these locations. It was further determined that the reconsolidation of subsoil material leads to reduced soil erodibility. The fill slope material exhibited lower runoff and soil loss than the cutslope material at both study locations.

K-values for study soils were calculated with the prediction equation, using site specific input variables. While the topsoil K-values indicated little relative change in value with stockpiling, the K-values of the fill slope material differed from the cutslope where it was obtained. The fill slope materials were found to have K-values about 5% less than the native subsoil materials from which they were derived.

While some highway construction activities would clearly lead to increased soil erodibility, it is evident from the study that the excavation and reconsolidation of compacted subsoil materials in fill situations can result in reduced soil erodibility. Measurements or estimates of soil permeability and structure indices for soil materials in highway construction would appear to allow reliable calculation of K-values with the prediction equation.

1/ Introduction

Soil erodibility is a term that is used to describe the relative inherent resistance of a soil to the detachment, entrainment and transport forces of rainfall/runoff. Erodibility is a complex property dependent on infiltration capacity, and the soil's physical and chemical properties related to the detachment and transport processes of rainfall/runoff. While complex, soil erodibility remains an important parameter in the application of soil erosion and sedimentation prediction equations used to solve related rural and urban environmental issues. The K-factor is an erodibility index that has been used extensively in the US and Canada as a component of the Universal Soil Loss Equation (USLE) [7]. When used in conjunction with the USLE, the K-factor is an average annual value.

The K-factor and associated USLE have been used extensively in the US and Canada for the control of soil erosion and sedimentation associated with the construction of highways and rights-of-way [1]. This soil erosion prediction technology has proven useful in highway route selection processes, as well as for the planning and construction of erosion control measures, and sedimentation structures.

In applications of the USLE to highway construction issues, there has been some debate over the selection of soil erodibility values for practices unique to highway construction. For example, does fill slope soil compacted to Ministry specifications have the same soil erodibility value as the native soil? Similarly, does topsoil dressing material stockpiled for up to several years maintain the soil erodibility value of the native topsoil? While these questions have remained unanswered, the soil erodibility values of native soil materials have been used for application to highway construction.

2/ Objectives

A study has been developed to:

a) establish the magnitude of change in soil erodibility that occurs when subsoil material is reconsolidated for fill in highway construction;

b) establish the magnitude of change in soil erodibility that occurs when topsoil dressing material is stockpiled for periods greater than one year.

3/ Study Approach

A two-phased approach was developed to address the study objectives. Firstly, the potential changes in soil erodibility that occur when topsoil or subsoil is stockpiled or reconsolidated, at highway construction sites, were hypothesized. This was done for a wide range of soil textures by changing input variables of the soil erodibility prediction equation. Secondly, the effect of topsoil storage and subsoil reconsolidation on soil erodibility was measured using rainfall simulation techniques on two highway construction sites.

4/ Methods

4.1/ Soil Erodibility Prediction

The soil erodibility prediction equation [7] was used to predict changes in soil erodibility of 15 different soil textures when soil permeability and soil structural input values were changed from minimum to maximum values. The prediction equation is:

$$100\,K = 0.1317\left[2.1\,M^{1.4}(10^{-4})(12 - a) + 3.25\,(b - 2) + 2.5\,(c - 3)\right]$$

Where K = soil erodibility (Mg ha h ha^{-1} MJ^{-1} mm^{-1})

M = (% silt) (100 - % clay)

a = % organic matter

b = soil structural code

c = soil permeability code

In highway construction applications of the soil erodibility prediction equation, the soil structure, and permeability input parameters are the most likely to differ from native soil values. The soil structure and permeability codes used in the computation are shown as follows:

Soil Structure Index	Definition
1	Very fine granular (< 1 mm)
2	Fine granular (< 2 mm)
3	Medium/coarse granular (2-10 mm)
4	Blocky, platy, massive (> 10 mm)

Soil Permeability Index	Definition
1	Very rapid (> 50 cm/h)
2	Rapid (15-50 cm/h)
3	Moderately rapid (2.5-15 cm/h)
4	Moderately slow (0.5-2.5 cm/h)
5	Slow (0.02-0.5 cm/h)
6	Very slow (< 0.02 cm/h)

The organic matter level of the soils was assumed to be 2% for all textures evaluated, except for the sands and loamy sands which were assumed to have 1% organic matter.

4.2/ Study Locations

Two highway construction sites were chosen to study in situ changes in soil erodibility associated with conventional highway construction practices. The first site was located at Highway 115 and County Road 10, east of the bridge construction site. The second study site was located north of Steeles Avenue at the burrow pit excavation site used for bridge construction, at the future Highways 427 & 407 interchange.

At both study locations, the soils were graded in 2:1 slopes and prepared to MTO specifications with MTO equipment. At the Highway 115 site, topsoil was obtained from a stockpile approximately 0.5 miles from the study site. Topsoil from both the surface of, and from the middle-bottom of the stockpile were applied as top-dressing, in two 12 feet widths, from the top to bottom of the 2:1 cut slope.

Adjacent to the top-dressed treatments, two subsoil treatments were prepared for study. The first subsoil treatment was the cut slope material. A second treatment was created by stripping the cutslope material to a depth of approximately 1 foot. The excavated material was then placed back on the slope and reconsolidated with heavy Ministry equipment to represent fill material.

The study site at Highways 427 & 407 was prepared in a similar fashion. However, the reconsolidated subsoil was approximately 0.5 feet in depth.

4.3/ Field Procedures

Runoff and erosion plots (1 m^2) were established on each of the four treatments in triplicate. Each plot consisted of a three-sided metal boundary with the open side in the downslope position. A metal lip and trough were installed at the open end to stabilize the soil at the lower boundary and collect runoff [5].

The day prior to rainfall simulation, all plots were prewetted with approximately one inch of water, over a three hour period. The water was applied from a watering can onto the soil surface which was covered with burlap filter. This prewetting assured that all plots would be either at, or near, field capacity at the beginning of rainfall simulation the following day.

Simulated rainfall was applied to each plot at an intensity of 2.67 mm min^{-1} for a duration of 10 minutes [4]. Runoff volumes were recorded and sampled after the 10 minute rainfall. Approximately 100 ml sub-samples of runoff were obtained in duplicate for laboratory analysis.

Surface soil samples (0-20 cm) were collected for soil characterization. Bulk density cores (100 cc) were obtained in triplicate for each soil treatment. These cores also provided soil materials for the determination of the antecedent soil moisture. Soil cores (341.81 cc) were also obtained in duplicate to measure hydraulic conductivity in the laboratory.

4.4/ Laboratory Procedures

Soil samples were analyzed in the laboratory for particle size distribution, organic matter content, pH, calcium carbonate, bulk density, and hydraulic conductivity, according to standard methods described by McKeague (1978). Soil moisture content was determined gravimetrically.

The sediment concentration in runoff was determined gravimetrically in duplicate by filtering runoff through pre-weighed 0.45 µm filters under vacuum pressure.

4.5/ Statistical Procedures

T-tests were performed to determine whether any significant differences in runoff or soil loss existed between the two topsoil treatments and again between the two subsoil treatments. The SAS computer software [3] was utilized at a significance level of $P > 0.05$.

5/ Results

Soil erodibility (K) is one of the six major factors that determine the soil loss rate in applications of the USLE for farmland or construction areas. The K-value for a particular soil can be measured directly from erosion plot data [7], or predicted with a soil erodibility equation or nomograph [6]. All applications of the USLE in Canada have used values calculated with the soil erodibility equation and nomograph. The error of estimate based on the data used for derivation indicates that of 100 K-values, 68 would be within 6.4% of the true value, 90 within 11%, and 99 within 17%.

For the major soils of Ontario, K-values have been calculated to range from < 0.05 to > 0.50. The more than 10-fold range in its magnitude emphasizes the importance of the soil factor in the prediction of sediment loss. The K-factor combines the effect of the soil's water intake capacity, and its susceptibility to detachment and transport by rainfall/runoff. A first approximation of the K-value may be obtained using only the particle size and organic matter data.

5.1/ Predicted Variation in Soil Erodibility

The soil erodibility prediction equation [7] was used to predict variations in soil K-values for 15 hypothetical soils when only the soil structure and permeability indices were changed. The predicted variation in soil erodibility (K) for the 15 soil textures is shown in summary (Table 1) and in total (Appendix A).

The soils studied varied from sands to heavy clay textures with clay contents ranging from < 10% to > 40%. The textures of the 15 soils studied are plotted on a textural triangle in Appendix B. The soil erodibility values (K_{approx}) for the 15 soils, obtained on the basis of soil texture and organic matter data, ranged from 0.02 (negligible) to 0.36 (moderately severe) (Table 1).

Table 1 also reports variation in K-values when structure and permeability values are maximized both independently and jointly. When the soil structure index is maximized while permeability is held constant, the range of soil erodibility values increased from 0.09 (negligible) to 0.43 (severe). Similarly, the maximization of the soil permeability index, while holding the soil structure index constant, leads to a slightly higher range of K-values from 0.10 (negligible) to 0.44 (severe). When both the structure and permeability indices are maximized (K_{max}) the range of K-values is further increased from 0.16 (slight) to 0.50 (very severe).

Table 1/ Predicted variation in soil erodibility (K) of 15 soil textures with variation of permeability and structural indices

			K Variation $^{\alpha}$			
	Soil Texture	K_{approx} $^{\beta}$	Structure	Permeability	K_{max} $^{\tau}$	K_{max}/K_{approx}
		(3,2) $^{\delta}$	(3,4)$^{\delta}$	(6,2)$^{\delta}$	(6,4)$^{\delta}$	
1	C	.02 (1)*	0.09	.10	.16 (2)	8.0
2	C	.04 (1)	0.11	.12	.18 (2)	4.5
3	C	.08 (1)	0.15	.16	.22 (2)	2.8
4	HC	.01 (1)	0.08	.09	.15 (1)	15.0
5	S	.03 (1)	0.10	.11	.17 (2)	5.7
6	LS	.09 (1)	0.16	.17	.23 (2)	2.6
7	SL	.02 (1)	0.09	.10	.16 (2)	8.0
8	SL	.14 (1)	0.21	.22	.28 (2)	2.0
9	SL	.29 (2)	0.36	.37	.43 (4)	1.5
10	SC	.01 (1)	0.08	.09	.15 (1)	15.0
11	SCL	.04 (1)	0.11	.12	.18 (2)	4.5
12	SiC	.16 (2)	0.23	.24	.30 (3)	1.9
13	SiCL	.24 (2)	0.31	.32	.38 (3)	1.6
14	SiL	.31 (3)	0.38	.39	.45 (4)	1.6
15	SiL	.36(3)	0.43	.44	.50 (4)	1.4

β K_{approx} = first approximation of K obtained without structure/permeability input

* Soil erodibility class from Wall et al., 1984. Soil erosion interpretation for soils of the Regional Municipality of Haldimand-Norfolk

α Changes in K when structure index is maximized while holding permeability index constant or permeability index maximized while holding structure index constant

τ K_{max} determined with maximum value of both the soil structure (4) and permeability (6) indices

δ Soil permeability and structure index values

The ratio of K_{max}/K_{approx} indicates the effect that the soil structure and permeability indices can have on soil erodibility values (Table 1). For the SiL, SiCl, and SiC soils, the soil erodibility values increased from 1.4 to 1.9 fold, while for the S, SL, LS, and SCl soils a 2 to 8 fold increase was found. The LC, C, and SC soils have increases of K that ranged up to 15 fold. While the K-values changed by orders of magnitude, the relative soil erodibility usually only changed by one class when maximum values of the soil structure and permeability indices were used.

Tables 2 and 3 show the predicted range of K-values for the soil materials found at the highway construction field locations when the soil permeability and structure indices are varied. At the Highway 115 location, the topsoil and subsoil materials were observed to have contrasting erodibilities (0.23 vs 0.65) (Table 2). The topsoil materials were computed to be less erodible (0.14-0.37) than the subsoil materials (0.56-0.79). Table 3 indicates that the predicted erodibility of the topsoil (0.13-0.36) and subsoil (0.18-0.41) materials at the Highway 427 site are similar.

The topsoil material at the Highway 115 location had a K-value (first approximation) of 0.23 (Table 2). If the soil permeability index, or structure index, was increased to its maximum value independently, while holding the other constant, the prediction equation indicates that the K-value would increase to 0.30. While the increase (0.23-0.30) in K-value represents approximately a 35% increase in the absolute value, the soil erodibility class of the material remains unchanged (Class 2, slight erodibility).

However, if both the soil structure and permeability index are changed simultaneously to maximum values, the predicted K-value represents a 60% increase in the K_{approx} value, and increases the soil erodibility class of this material from 2 (slight) to 3 (moderately severe).

The predicted soil erodibility of the subsoil material at the Highway 115 location was $K_{approx} = 0.65$ (Class 5, very severe erosion potential) (Table 2). Increasing the soil structure or permeability indices, independently, resulted in higher K-values (0.72). Increasing both indices to maximum values, in the prediction equation, gave a K-value of 0.79. This K-value is approximately 22% greater than the K_{approx} value, but is in the same general soil erodibility (Class 5).

Table 2/ Predicted K-values for Highway 115 topsoil and subsoil materials

Topsoil	Perm Class	Structure Class			
		1	2	3	4
	1	.1475	.1800	.2125	.2450
	2	.1725	.2050	.2375	.2700
	3	.1975	.2300*	.2625	.2950
	4	.2225	.2550	.2875	3200
	5	.2475	.2800	.3125	.3450
	6	.2725	.3050	.3375	.3700

Subsoil	Perm Class	Structure Class			
		1	2	3	4
	1	.5675	.6000	.6325	.6650
	2	.5925	.6250	.6575	.6900
	3	.6175	.6500*	.6825	.7150
	4	.6425	.6750	.7075	.7400
	5	.6675	.7000	.7325	.7650
	6	.6925	.7250	.7575	.7900

*First approximation of K_{approx}

5.2/ Measured Variation in Soil Erodibility

In order to provide insight into variation of soil erodibility of topsoil and subsoil materials used in highway construction, field measurements of soil properties, runoff volumes, and soil loss from simulated rainfall events were taken at two locations. Photographs of the field sampling locations at Highways 115 and 427 construction sites are found in Appendix C.

Table 3/ Predicted K-values for Highway 427 topsoil and subsoil materials

Topsoil	Perm Class	Structure Class			
		1	2	3	4
	1	.1375	.1700	.2025	.2350
	2	.1625	.1950	.2275	.2600
	3	.1875	.2200*	.2525	.2850
	4	.2125	.2450	.2775	.3100
	5	.2375	.2700	.3025	.3350
	6	.2625	.2950	.3275	.3600

Subsoil	Perm Class	Structure Class			
		1	2	3	4
	1	.1875	.2200	.2525	.2850
	2	.2125	.2450	.2775	.3100
	3	.2375	.2700*	.3025	.3350
	4	.2625	.2950	.3275	.3600
	5	.2875	.3200	.3525	.3850
	6	.3125	.3450	.3775	.4100

*First approximation of K_{approx}

5.2.1/ Soil Physical Properties

The physical properties of the soil at the study locations are summarized in Tables 4 and 5. The topsoil and subsoil treatments (stockpiled or reconsolidated) have little effect on the particle size distribution of the materials. The texture of the topsoil treatments and subsoil treatments at the Highway 115 site are loam and silt, respectively (Table 4). At the Highway 427 site, both the topsoil and subsoil treatments are clay loam in texture (Table 5). Similarly, the antecedent soil moisture content of the soil materials did not differ significantly between soil treatments (Tables 4 and 5).

Measurements of soil hydraulic conductivity and bulk density were made as proxies of the soil permeability and structure indices employed in the prediction of soil erodibility (Wischmeier and Meyer, 1971). The bulk densities of the topsoil treatments at both Highways 115 (Table 4) and 427 (Table 5) are similar. This observation would suggest that the stockpiling of the topsoil material had a limited effect on soil structural properties.

However, the bulk density of the subsoil treatments differs for both soils studied (Tables 4 and 5). In both cases, the reconsolidated subsoil materials have bulk densities that are 5-7% lower than those for the natural soil materials. The observed decrease in bulk density should reduce the erodibility of these soil materials.

The K_{approx} values for the topsoil and subsoil materials, at the Highway 427 location, were 0.22 and 0.27, respectively (Table 3). An independent increase of the soil structure or permeability index, in the prediction equation, results in approximately a 30% increase in the predicted value, and changes the soil erodibility by no more than one class, from 2 (slight) to 3 (moderately severe). When both the structure and permeability indices are maximized, in the prediction equation, the K-values of the topsoil and subsoil materials increase to 0.36 and 0.41. These K-values represent a 50-60% increase in the K_{approx} value and, in the case of the subsoil material, increase the soil erodibility class from 2 (slight) to 4 (severe).

Soil hydraulic conductivity values (cm h^{-1}), and the corresponding soil permeability index for each of the soil treatments, are shown in Tables 4 and 5. The topsoil treatments at the Highway 115 site have the same permeability index (5) (Table 4). The subsoil treatments at Highway 115 (Table 4) and the topsoil treatment at Highway 427 (Table 5) differ in permeability by one class. The stockpiled topsoil and the reconsolidated subsoil materials are more permeable in each case. At the Highway 427 site, the soil permeability index for the reconsolidated subsoil was greater by 2 classes (Table 5).

At the Highway 115 site, the topsoil/stockpiled treatment K-values were calculated to be 0.28; the subsoil/reconsolidated treatment K-values were 0.70 and 0.65, respectively. For the Highway 427 site, the topsoil/stockpiled treatment K-values were calculated to be 0.27 and 0.25, while the subsoil/reconsolidated treatment K-values were 0.41 and 0.33, respectively.

Table 4/ Soil properties of topsoil and subsoil materials at the Highway 115 study site

Treatment	Textural Class	Sand	Silt	Silt + VFS	Clay	Organic Matter	Moisture	Bulk Density	Hydraulic Conductivity	
		Percent						g/cc	cm/h	I*
Topsoil	L	41.5	38.0	52.6	20.5	4	22	1.16	0.42	5
Topsoil stockpile	L	43.8	36.9	52.0	19.3	4	26	1.17	0.11	5
Subsoil	Si	7.7	82.5	82.5	9.8	0	20	1.63	0.70	4
Subsoil reconstruction	Si	7.2	86.4	86.4	6.4	0	19	1.44	7.40	3

* *Soil permeability index for the soil erodibility prediction equation*

Table 5/ Soil properties of topsoil and subsoil materials at the Highway 427 study site

Treatment	Textural Class	Sand	Silt	Silt + VFS	Clay	Organic Matter	Moisture	Bulk Density	Hydraulic Conductivity	
		Percent						g/cc	cm/h	I*
Topsoil	CL	32.7	38.3	54.0	29.0	3.5	26	1.25	0.18	5
Topsoil stockpile	CL	33.2	36.9	62.7	29.9	3.6	25	1.24	0.90	4
Subsoil	CL	24.8	44.5	52.5	30.7	0.9	22	1.54	0.01	6
Subsoil reconstruction	CL	21.1	43.4	50.0	35.5	1.0	21	1.41	0.63	4

* *Soil permeability index for the soil erodibility prediction equation*

5.2.2/ Runoff Volumes

The amount of runoff from a rainfall event provides an index of the potential erodibility of a soil material. The greater the runoff from a soil, the greater the potential for soil loss. Cumulative runoff volumes from simulated rainfall events are found in Appendices D and E.

Figures 1 and 2 show the mean runoff volumes from the topsoil and subsoil treatments at the Highway 115 study site. The topsoil treatments exhibited similar runoff volumes, but of the two there was a trend for the stockpiled topsoil to yield slightly greater runoff volumes (Figure 1). The reconsolidated subsoil had lower volumes of runoff than did the subsoil (Figure 2). This observation would suggest that the reconsolidated subsoil (fill material) would have a lower erosion potential than the subsoil (cut material).

Figures 3 and 4 show the mean runoff volumes from the topsoil and subsoil treatments at the Highway 427 site. For the topsoil treatments, the stockpiled topsoil yielded somewhat less runoff than the topsoil materials (Figure 3). Similarly, the reconsolidated subsoil material gave less runoff than the native subsoil material (Figure 4). These results suggest that the stockpiled topsoil and fill slope material may be less erodible than their associated native soils.

Statistical analysis of the data was performed for return period storms of 5, 10, and 25 years. All return period storms indicated that at both test sites, runoff was not significantly different ($P = 0.05$) between treatments of topsoil or subsoil.

5.2.3/ Soil Loss

Mean soil losses for each soil treatment, from simulated rainfall events for both study locations, are shown in Table 6. For the Highway 115 site, the stockpiled topsoil material yields significantly ($P = 0.05$) more sediment than the topsoil material while for the Highway 427, site the soil losses were similar for both the topsoil treatments. For the subsoil material studied, the soil loss from the cut-slope material (subsoil) was greater than that from the fill slope material (subsoil reconsolidated). However, these differences were statistically significant for only the Highway 115 location.

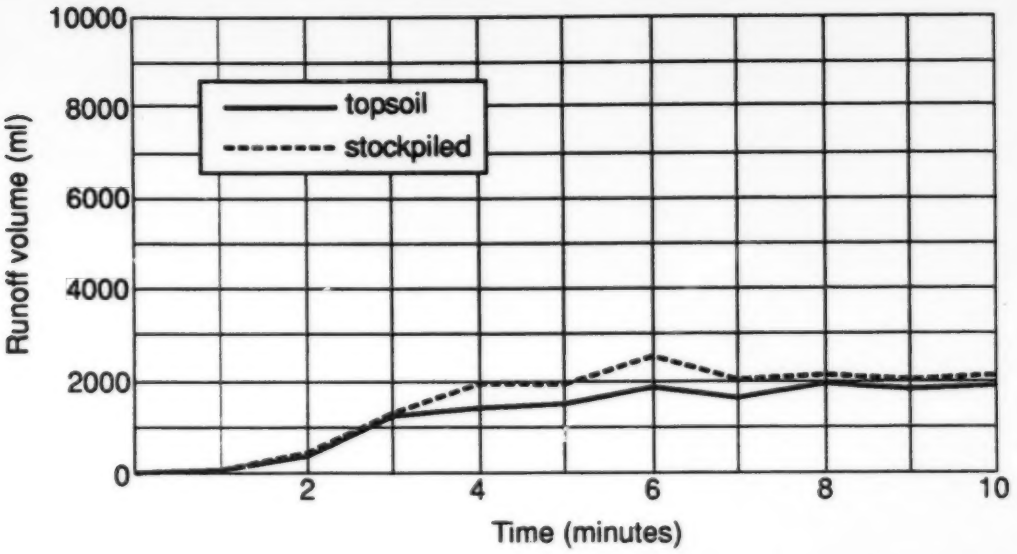


Figure 1/ Mean runoff volumes from topsoil treatments Highway 115

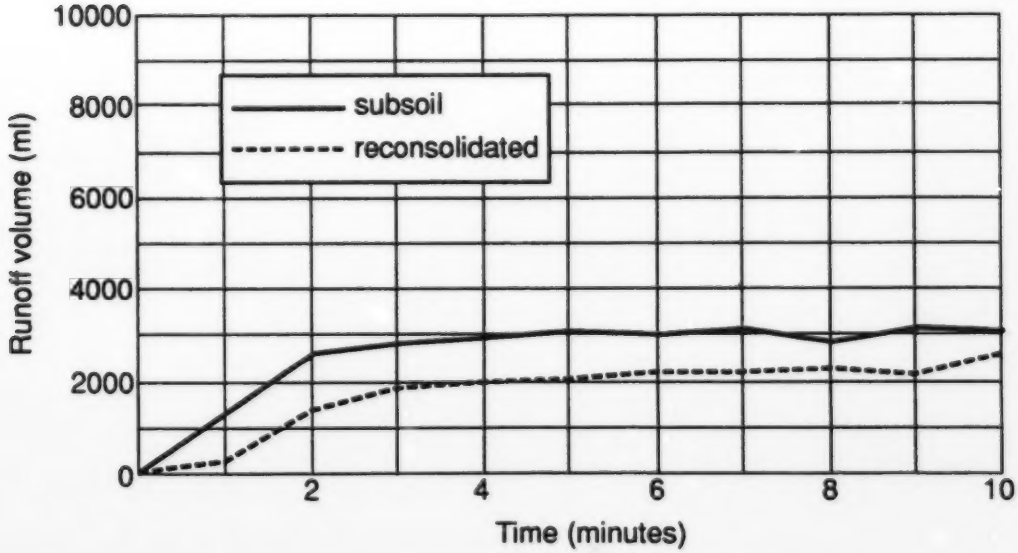


Figure 2/ Mean runoff volumes from subsoil treatments Highway 115

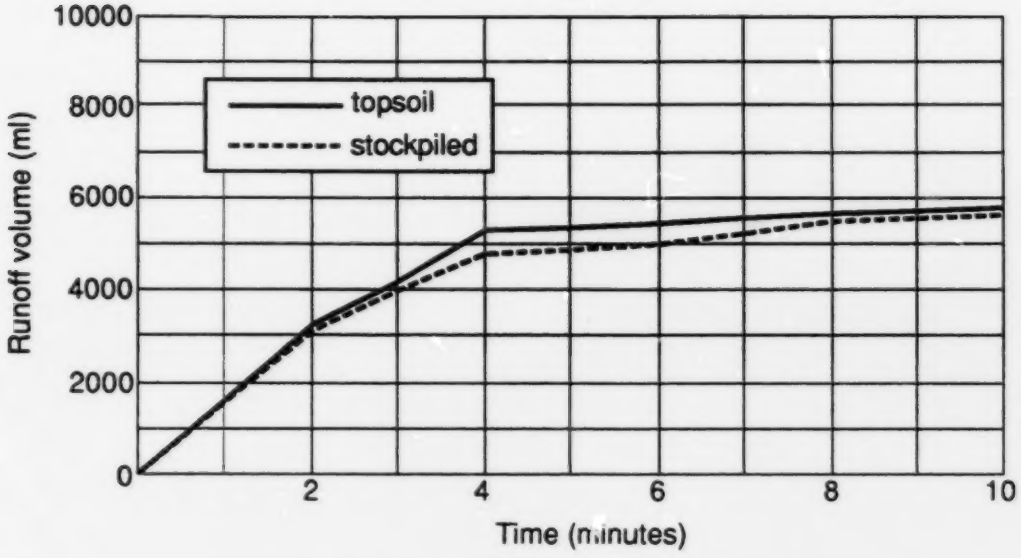


Figure 3/ Mean runoff from topsoil treatments Highway 427

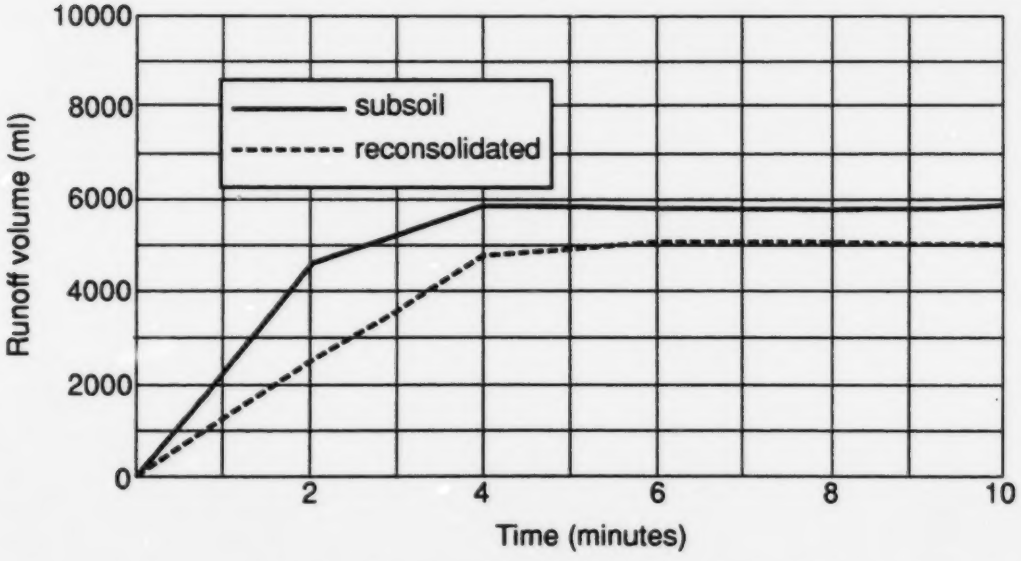


Figure 4/ Mean runoff from subsoil treatments Highway 427

6/ Summary and Conclusions

Predicted variation of soil erodibility (K-factor) was computed for 15 hypothetical soil materials by changing the input values of the soil permeability and structure indices. It was postulated that by changing the soil structure and permeability values, the magnitude of change of erodibility occurring to native soil materials under highway construction operations could be approximated. The K-values (first approximation) of the 15 soil materials used ranged from negligible (0.02) erosion potential to moderately severe (0.36) erosion potential.

When the soil permeability and structure indices were varied independently in the prediction equation, the resulting K-values were both higher or lower than the K-values, first approximation. However, the maximum K-values obtained by changing the permeability or structure indices independently, were approximately equal for all soil textures.

Joint variation of the soil permeability and structure indices produced maximum K-values. The magnitude of change was observed to vary with soil texture. When maximum values of the K-factor were compared to the first approximation of K-values, the following increases in K-values were observed:

Texture	Increase
SiL, SiCL, SiC	1.4 to 1.9 fold
S, SL, LS, SCL	2 to 8 fold
HC, C, SC	2 to 15 fold

While the maximum predicted K-values changed by orders of magnitude, the relative soil erodibility class (1 negligible, 2 slight, 3 moderately severe, 4 severe, 5 very severe) of the soil materials usually changed only by one class when maximum or minimum values of soil erodibility were determined.

The changes in soil erodibility resulting from highway construction activities were predicted and measured at two active highway construction locations (Highways 115 and 427). In both cases, the effects of topsoil stockpiling, and the reconsolidation of subsoil materials on soil erodibility values were evaluated.

The soil erodibility values (K_{approx}) of the topsoil materials studied were 0.22 to 0.23. When soil permeability and structure indices were maximized, the resulting K-factors were predicted to increase by approximately 60%, from 0.37 to 0.38. Field measurement of hydraulic conductivity and bulk density

values for the topsoil materials, indicated little change between the topsoil and stockpiled topsoil materials. The predicted K-value for the topsoil materials at Highway 115 and Highway 427, using measured permeability and structure indices, was 0.28 (5, 2) and 0.27-0.25 (5 or 4, 2), respectively. The stockpiled topsoil had little apparent effect on the measured K-values. The numbers reported in brackets are the values of the soil structure and permeability indices used in the calculation of the K-factor.

The soil erodibility (K_{approx}) values of the subsoil materials studied at Highways 115 and 427 were 0.65 and 0.27, respectively. When measured values of permeability and structure were used, the K-factor for the subsoil materials at Highway 115 were calculated to be 0.70 (subsoil, 4, 3) and 0.65 (subsoil stockpiled, 3, 2). At the Highway 427 site, the K-factors were calculated to be 0.41 (subsoil, 4, 3) and 0.33 (subsoil-reconsolidated, 4, 3). The subsoil reconsolidation which simulated fill slope preparation resulted in reduced soil erodibility potential.

Measured losses of runoff and soil, at the study sites, have supported predictions in change of soil erodibility values. At the Highway 115 site, runoff and soil loss values were the greatest for the stockpiled topsoil and subsoil treatments. For Highway 427 site, the runoff and soil loss from the topsoil treatments were similar, while for the subsoil treatments, the cut slope subsoil material had the greatest runoff and soil loss amounts. Runoff and soil losses from the subsoil treatments, suggest that the soil erodibility of the cut slope materials is higher than that for the fill slope material studied. Similarly, runoff and soil loss from topsoil treatments suggest little differences that would result in changes of erodibility when topsoil material is stockpiled.

Table 6/ Mean soil losses from simulated rainfall events at Highways 115 and 427

Site	Treatment	Soil Loss
		T/Ha
Hwy # 115	Topsoil	6[b]
	Topsoil stockpile	16[a]
	Subsoil	60[a]
	Subsoil reconsolidated	25[b]
Hwy # 427	Topsoil	14[a]
	Topsoil stockpile	13[a]
	Subsoil	6[a]
	Subsoil reconsolidated	4[a]

Treatments with same letters do not differ significantly (P = 0.05)

Analysis of the study results have lead to the following conclusions:

- Changes in the values of soil permeability and structure that may occur during highway construction, created significant changes in the absolute values of soil erodibility, that varied with soil texture. Soil textures with the greatest potential for variation were the HC, C, SC, and SCL, while the S, LS, SC changed to a lesser extent. The SiC, SiCL and SiL textures showed the least variation.

- While the absolute changes in K-value were significant for the 15 soils studied, the variation usually changed the potential soil erodibility by only one class.

- The use of measured soil properties to calculate soil erodibility values indicated that K-values of the topsoil and stockpiled topsoil were not significantly different.

The use of measured soil properties to calculate K-values for two subsoil materials indicated that the K-values for the subsoil reconsolidated (fill) were lower (< 5%) than those for the cut soil material. Changes in K-value would seldom change the soil erodibility by more than one class.

- Measured runoff and soil loss from highway construction sites supported K-values determined from site-specific input parameters.

7/ Study Team

The following study team members are acknowledged for their assistance in field data collection, laboratory analysis, data synthesis, and report preparation: I.J. Shelton, D.J. King, B.K. Hohner, S.F. Duvieusart.

Bibliography

[1] Clyde, C.G. "Erosion Control During Highway Construction," Utah State University, Water Research Laboratory, NCHRP Project 16-3, Volumes 1-3, 1976.

[2] McKeague, J.A. "Manual on Soil Sampling and Methods of Analysis," Canadian Society of Soil Science, Ottawa, Ontario, 1978.

[3] SAS Institute Inc., "SAS Introductory Guide for Personal Computers," Version 6 Edition, Cary, NC, USA, SAS Institute Inc., 111 pp., 1985.

[4] Tossell, R.W., W.T. Dickinson, R.P. Rudra, and G.J. Wall. "Portable Rainfall Simulator," Can. Agric. Eng., 29: 155-162, 1987.

[5] Wall, G.J. "Effectiveness of Erosion Control Measures," Research and Development Branch, Ontario Ministry of Transportation, Research and Development Project 22203, Toronto, 9 pp., 1990.

[6] Wischmeier, W.H. and L.D. Meyer. "Soil Erodibility On Construction Areas," J. Soil Water Cons. 26(5) 189-193, 1971.

[7] Wischmeier, W.H. and D.D. Smith. "Predicting Rainfall Erosion Losses - A Guide to Conservation Planning," U.S.D.A. Agric. Handb. No. 537. Washington, D.C., 1978.

Appendix A/ Effect of Variation of Soil Structure and Permeability Indices on Predicted Soil Erodibility of 15 Soil Materials

K-Values for various textures not represented in the MTO soil samples
- Various structure and permeability class combinations
- Organic matter assumed to be 2%, except for S & LS - 1 %

Clay #1	**% C**	**55**	**% S + vfS**	**10**
First Approximation of K		**0.02**		
Permeability Class		**Structure Class**		
	1	**2**	**3**	**4**
1	-0.0625	-0.03	0.0025	0.035
2	-0.0375	-0.005	0.0275	0.06
3	-0.0125	0.02	0.0525	0.085
4	0.0125	0.045	0.0775	0.11
5	0.0375	0.07	0.1025	0.135
6	0.0625	0.095	0.1275	0.16

Clay #2	**% C**	**60**	**% S + vfS**	**20**
First Approximation of K		**0.04**		
Permeability Class		**Structure Class**		
	1	**2**	**3**	**4**
1	-0.0425	-0.01	0.0225	0.055
2	-0.0175	0.015	0.0475	0.08
3	0.0075	0.04	0.0725	0.105
4	0.0325	0.065	0.0975	0.13
5	0.0575	0.09	0.1225	0.155
6	0.0825	0.115	0.1475	0.18

Clay #3	**% C**	**55**	**% S + vfS**	**30**
First Approximation of K		**0.08**		
Permeability Class		**Structure Class**		
	1	**2**	**3**	**4**
1	-0.0025	0.03	0.0625	0.095
2	0.0225	0.055	0.0875	0.12
3	0.0475	0.08	0.1125	0.145
4	0.0725	0.105	0.1375	0.17
5	0.0975	0.13	0.1625	0.195
6	0.1225	0.155	0.1875	0.22

Heavy Clay	% C	80	% S + vfS	10
First Approximation of K		0.01		

Permeability Class	Structure Class 1	2	3	4
1	-0.0725	-0.04	-0.0075	0.025
2	-0.0475	-0.015	0.0175	0.05
3	-0.0225	0.01	0.0425	0.075
4	0.0025	0.035	0.0675	0.1
5	0.0275	0.06	0.0925	0.125
6	0.0525	0.085	0.1175	0.15

Sand	% C	5	% S + vfS	5
First Approximation of K		0.03		

Permeability Class	Structure Class 1	2	3	4
1	-0.0525	-0.02	0.0125	0.045
2	-0.0275	0.005	0.0375	0.07
3	-0.0025	0.03	0.0625	0.095
4	0.0225	0.055	0.0875	0.12
5	0.0475	0.08	0.1125	0.145
6	0.0725	0.105	0.1375	0.17

Loamy Sand	% C	5	% S + vfS	15
First Approximation of K		0.09		

Permeability Class	Structure Class 1	2	3	4
1	0.0075	0.04	0.0725	0.105
2	0.0325	0.065	0.0975	0.13
3	0.0575	0.09	0.1225	0.155
4	0.0825	0.115	0.1475	0.18
5	0.1075	0.14	0.1725	0.205
6	0.1325	0.165	0.1975	0.23

Sandy Loam # 1	% C	15	% S + vfS	5
First Approximation of K		0.02		

Permeability Class	Structure Class 1	2	3	4
1	-0.0625	-0.03	0.0025	0.035
2	-0.0375	-0.005	0.0275	0.06
3	-0.0125	0.02	0.0525	0.085
4	0.0125	0.045	0.0775	0.11
5	0.0375	0.07	0.1025	0.135
6	0.0625	0.095	0.1275	0.16

Sandy Loam # 2	% C	10	% S + vfS	25
First Approximation of K		0.14		

Permeability Class	Structure Class 1	2	3	4
1	0.0575	0.09	0.1225	0.155
2	0.0825	0.115	0.1475	0.18
3	0.1075	0.14	0.1725	0.205
4	0.1325	0.165	0.1975	0.23
5	0.1575	0.19	0.2225	0.255
6	0.1825	0.215	0.2475	0.28

Sandy Loam # 3	% C	5	% S + vfS	45
First Approximation of K		0.29		

Permeability Class	Structure Class 1	2	3	4
1	0.2075	0.24	0.2725	0.305
2	0.2325	0.265	0.2975	0.33
3	0.2575	0.29	0.3225	0.355
4	0.2825	0.315	0.3475	0.38
5	0.3075	0.34	0.3725	0.405
6	0.3325	0.365	0.3975	0.43

Sandy Clay First Approximation of K	% C	45 0.01	% S + vfS	5
Permeability Class		**Structure Class**		
	1	2	3	4
1	-0.0725	-0.04	-0.0075	0.025
2	-0.0475	-0.015	0.0175	0.05
3	-0.0225	0.01	0.0425	0.075
4	0.0025	0.035	0.0675	0.1
5	0.0275	0.06	0.0925	0.125
6	0.0525	0.085	0.1175	0.15

Sandy Clay Loam First Approximation of K	% C	30 0.04	% S + vfS	10
Permeability Class		**Structure Class**		
	1	2	3	4
1	-0.0425	-0.01	0.0225	0.055
2	-0.0175	0.015	0.0475	0.08
3	0.0075	0.04	0.0725	0.105
4	0.0325	0.065	0.0975	0.13
5	0.0575	0.09	0.1225	0.155
6	0.0825	0.115	0.1475	0.18

Silty Clay First Approximation of K	% C	45 0.16	% S + vfS	45
Permeability Class		**Structure Class**		
	1	2	3	4
1	0.0775	0.11	0.1425	0.175
2	0.1025	0.135	0.1675	0.2
3	0.1275	0.16	0.1925	0.225
4	0.1525	0.185	0.2175	0.25
5	0.1775	0.21	0.2425	0.275
6	0.2025	0.235	0.2675	0.3

Silty Clay Loam	% C	35	% S + vfS	55
First Approximation of K		0.24		

Permeability Class	Structure Class 1	2	3	4
1	0.1575	0.19	0.2225	0.255
2	0.1825	0.215	0.2475	0.28
3	0.2075	0.24	0.2725	0.305
4	0.2325	0.265	0.2975	0.33
5	0.2575	0.29	0.3225	0.355
6	0.2825	0.315	0.3475	0.38

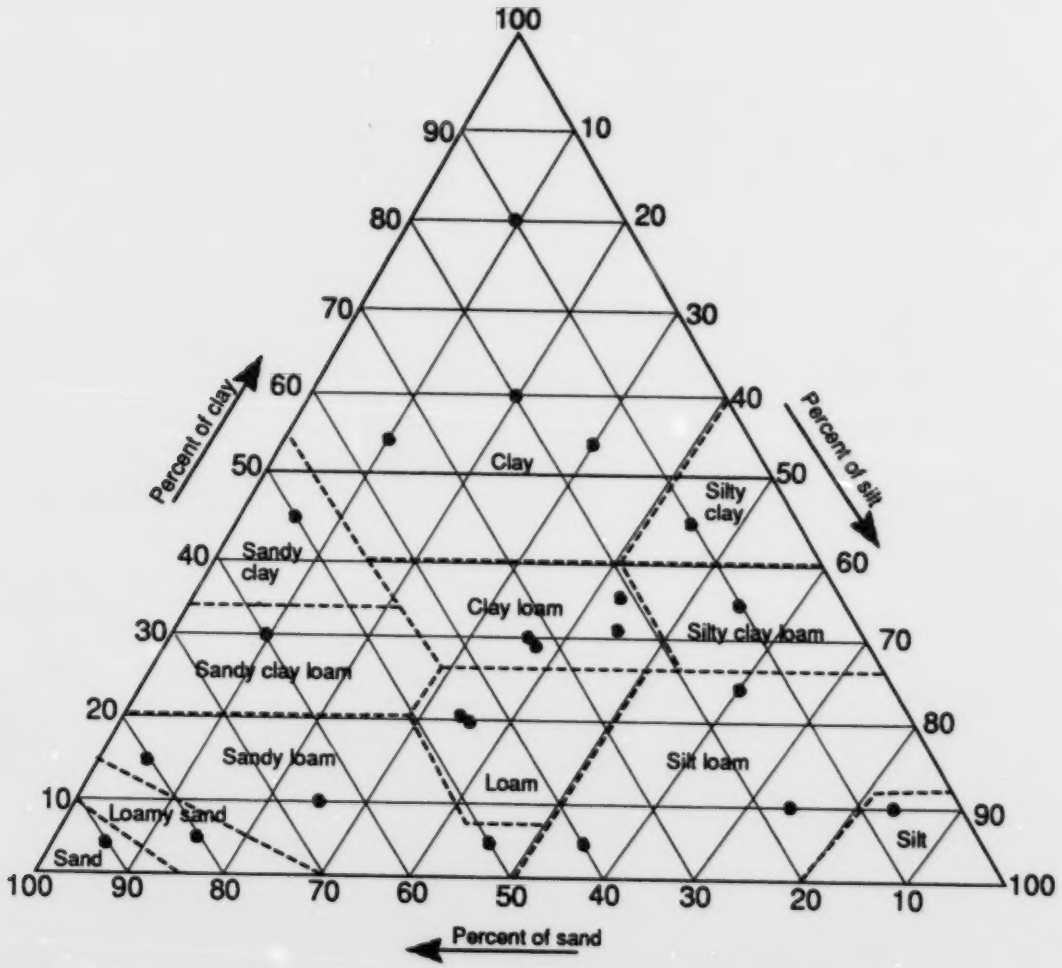
Silt Loam # 1	% C	25	% S + vfS	60
First Approximation of K		0.31		

Permeability Class	Structure Class 1	2	3	4
1	0.2275	0.26	0.2925	0.325
2	0.2525	0.285	0.3175	0.35
3	0.2775	0.31	0.3425	0.375
4	0.3025	0.335	0.3675	0.4
5	0.3275	0.36	0.3925	0.425
6	0.3525	0.385	0.4175	0.45

Silt Loam # 2	% C	5	% S + vfS	55
First Approximation of K		0.36		

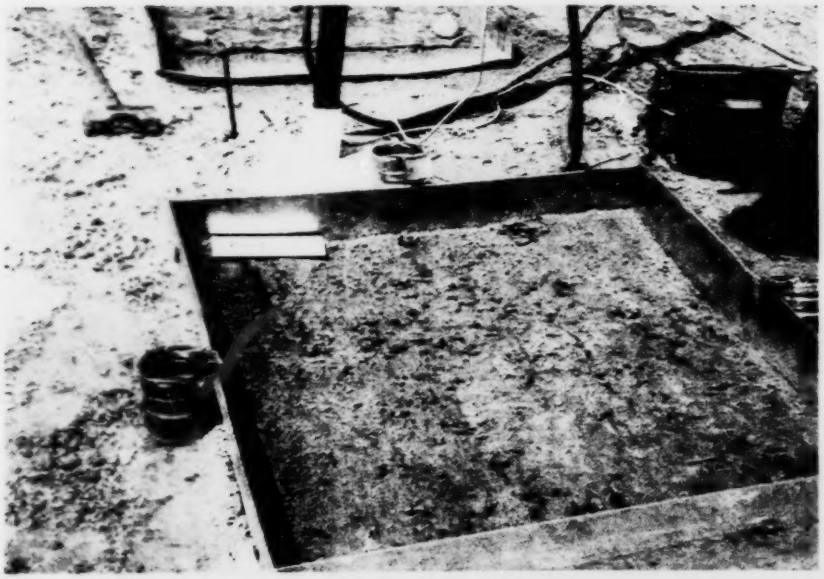
Permeability Class	Structure Class 1	2	3	4
1	0.2775	0.31	0.3425	0.375
2	0.3025	0.335	0.3675	0.4
3	0.3275	0.36	0.3925	0.425
4	0.3525	0.385	0.4175	0.45
5	0.3775	0.41	0.4425	0.475
6	0.4025	0.435	0.4675	0.5

Appendix B/ Soil Texture of the 15 Soil Materials Studied for Potential Changes in Soil Erodibility

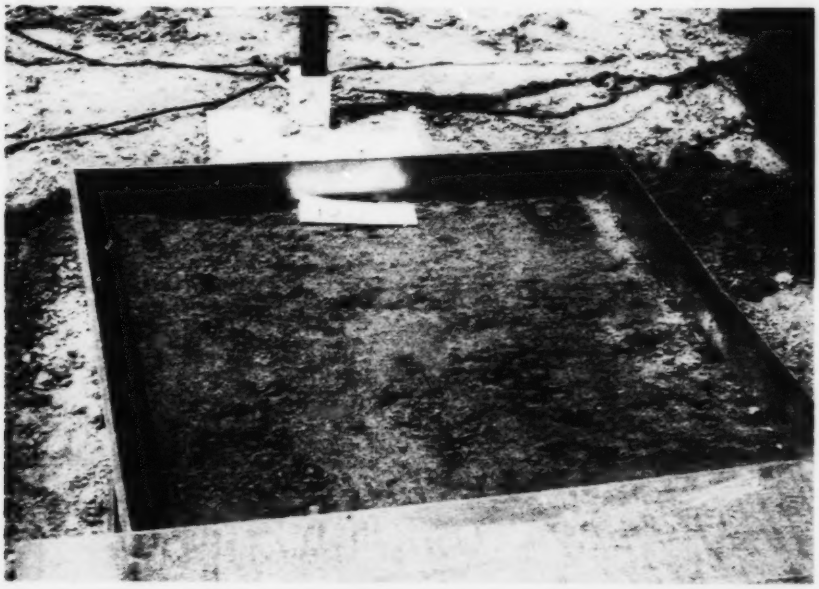


Appendix C/ Photographs of Field Sampling Locations at Highways #115 and #427

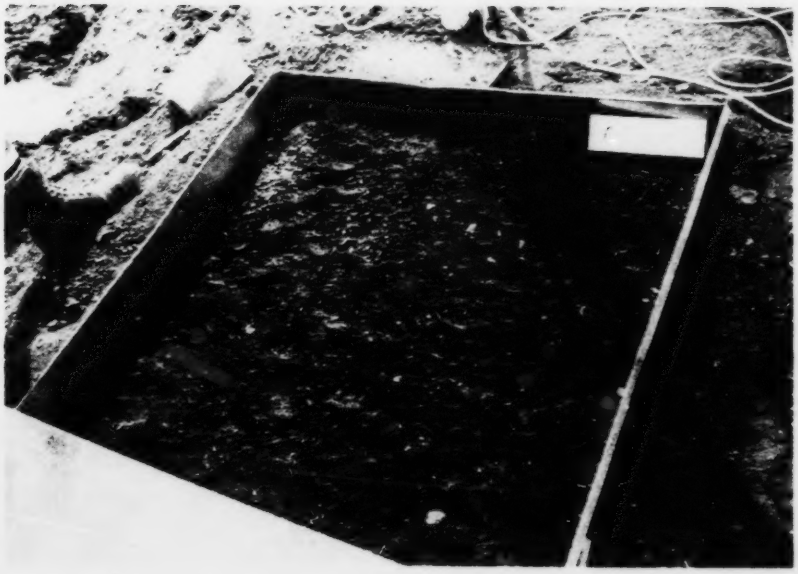
Peterborough Site



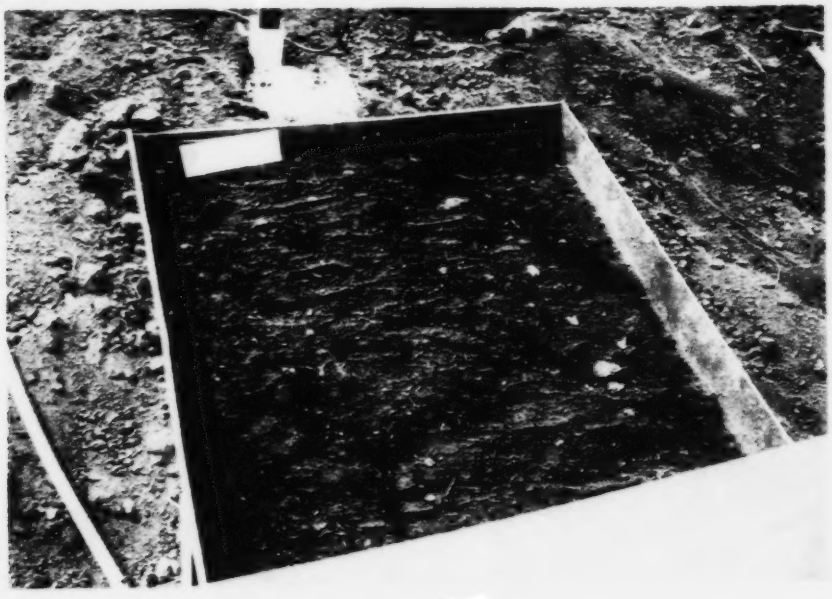
Subsoil



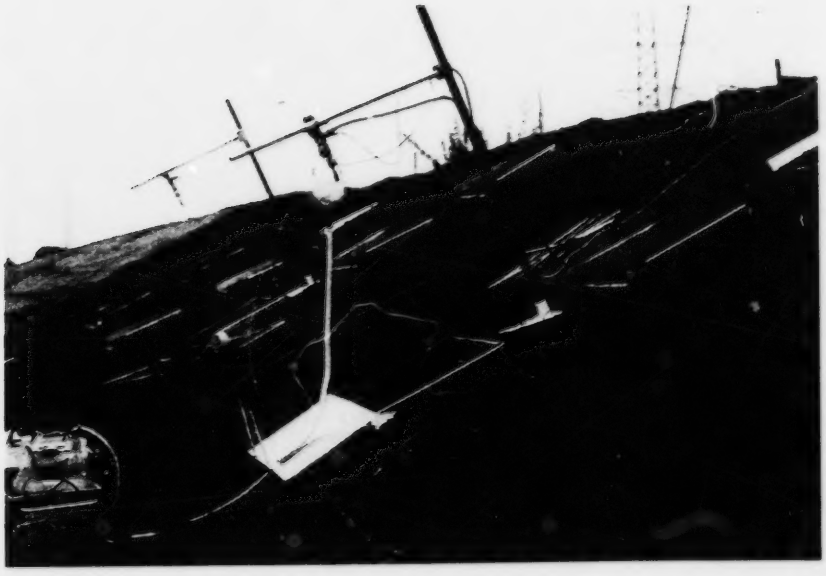
Subsoil Reconsolidated



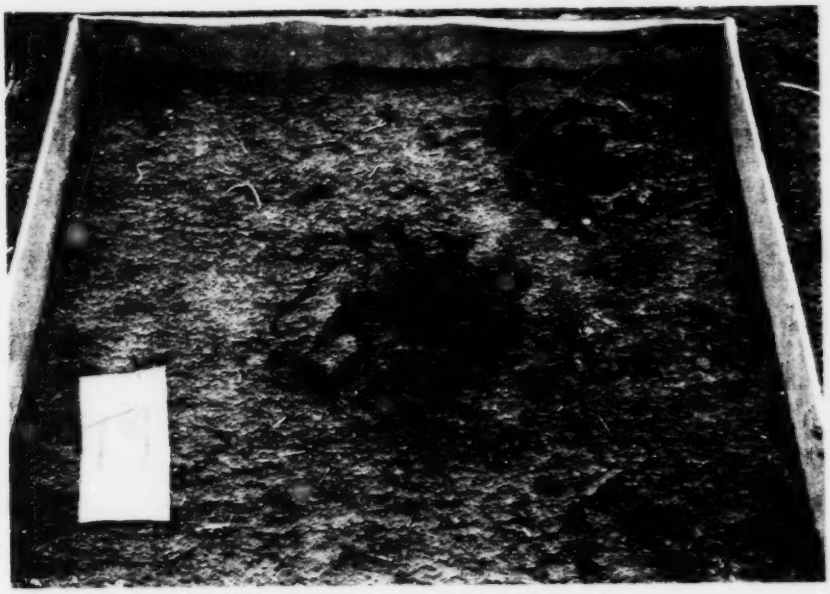
Topsoil Stored



Topsoil

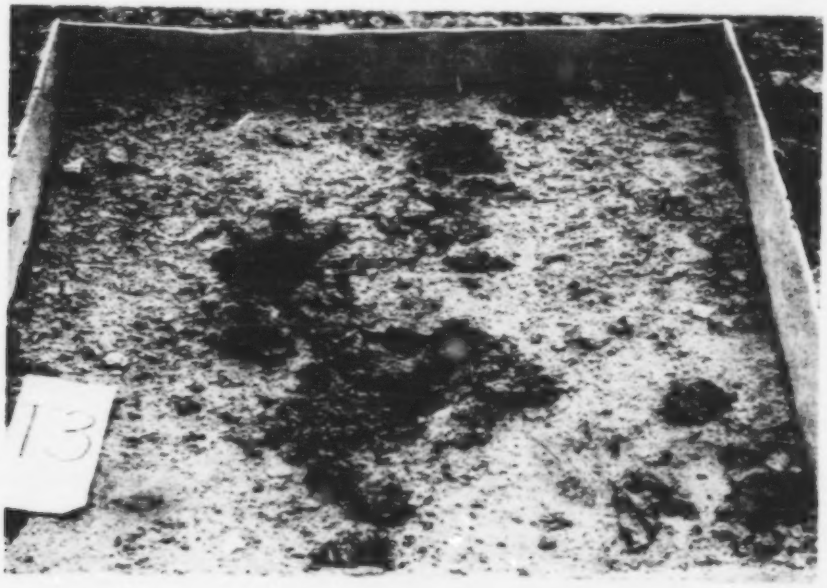


Toronto Site

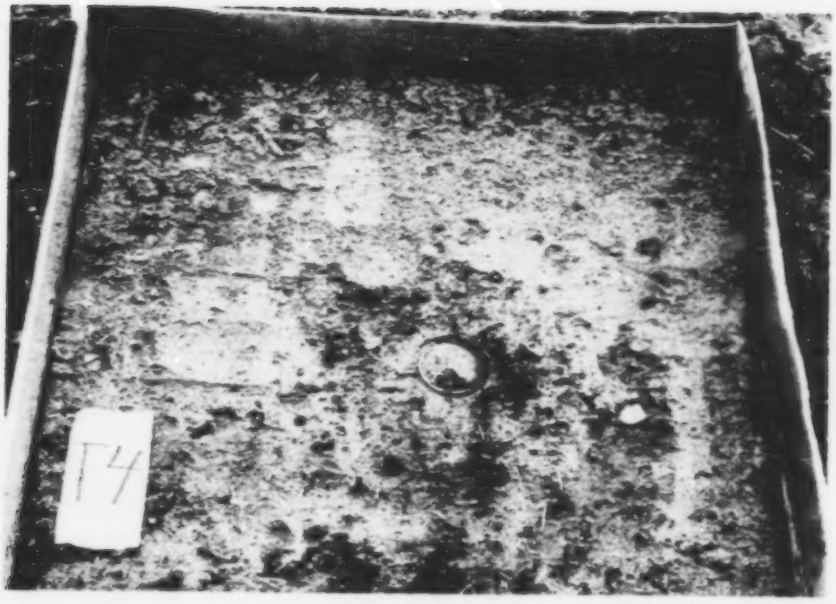


Topsoil

Topsoil Stored

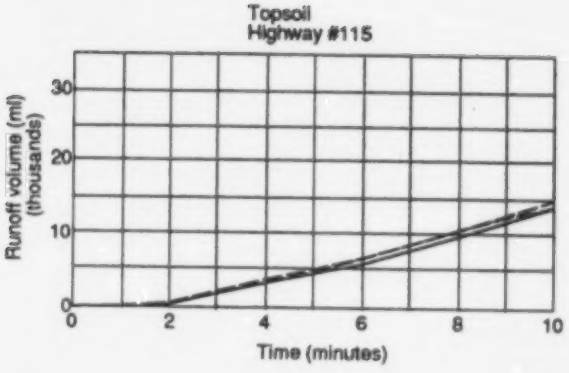


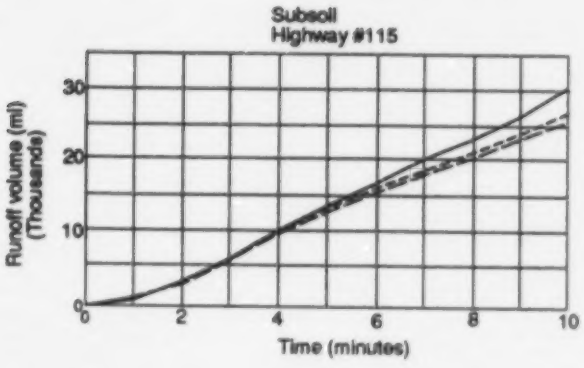
Subsoil Reconsolidated

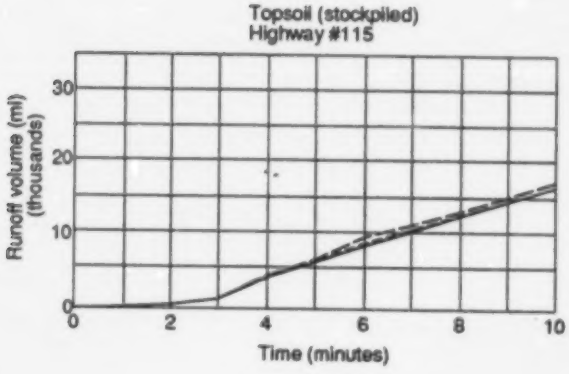


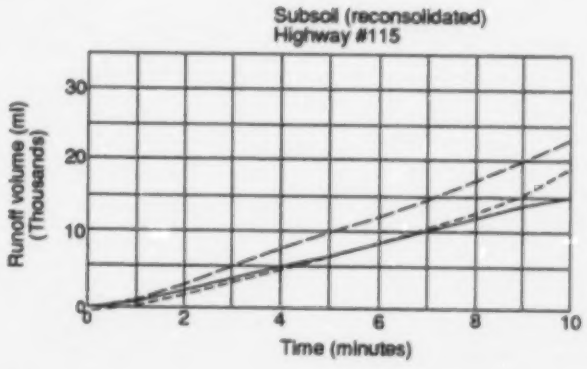
Subsoil

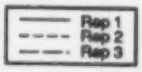
Appendix D/ Cumulative Volumes at Highway #115 Site











Site: Highway #115 Intensity: 16 cm/h August 4, 1990
Topsoil

Plot 4-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	0	0
2	400	400
3	1050	1450
4	1500	2985
5	1450	4400
6	1800	6200
7	1625	7825
8	1950	9775
9	1800	11575
10	1900	13475

Regression Output	
Constant	-1895.45
Std Err of Y Est	965.26
R Squared	0.96428
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	1434.546
Std. Err. of Coef.	92.03393

Plot 4-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	0	0
2	750	750
3	1350	2100
4	1600	3700
5	1600	5300
6	1750	7050
7	1550	8600
8	1900	10500
9	1700	12200
10	1600	13800

Regression Output	
Constant	-1609.09
Std Err of Y Est	734.7023
R Squared	0.980378
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	1485.455
Std. Err. of Coef.	70.05112

Plot 4-3

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	0	0
2	300	300
3	1300	1600
4	1450	3050
5	1750	4800
6	2000	6800
7	1900	8550
8	2000	10550
9	1900	12450
10	2150	14600

Regression Output	
Constant	-2081.82
Std Err of Y Est	1052.011
R Squared	0.963965
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	1556.364
Std. Err. of Coef.	100.3053

Site: Highway #115 **Intensity: 16 cm/h** **August 4, 1990**
Topsoil (Stockpiled)

Plot 3-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	0	0
2	750	750
3	1550	2300
4	2000	4300
5	2000	6300
6	2000	8300
7	2000	10300
8	2100	12400
9	2100	14500
10	2200	16700

Regression Output	
Constant	-2034.09
Std Err of Y Est	945.7759
R Squared	0.977569
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	1785.909
Std. Err. of Coef.	90.17619

Plot 3-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	0	0
2	600	600
3	1350	1950
4	2000	3950
5	1750	5700
6	2150	7850
7	2100	9950
8	2400	12350
9	2050	14400
10	2250	16650

Regression Output	
Constant	-2236.36
Std Err of Y Est	1140.056
R Squared	0.969544
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	1781.818
Std. Err. of Coef.	105.2676

Plot 3-3

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	0	0
2	750	750
3	1250	2000
4	1900	3900
5	1900	5800
6	3600	9400
7	2000	11400
8	2125	13525
9	2000	15525
10	2125	17650

Regression Output	
Constant	-2412.5
Std Err of Y Est	1236.773
R Squared	0.967693
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	1936.136
Std. Err. of Coef.	117.9217

Site: Highway #115 **Intensity:** 16 cm/h **August 4, 1990**
Subsoil

Plot 1-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	1000	1000
2	2700	3700
3	3000	6700
4	3250	9950
5	3300	13250
6	3250	16500
7.08	3700	20200
8	2800	23000
9	3700	26700
10	3600	30300

Regression Output	
Constant	-1961.15
Std Err of Y Est	854.5492
R Squared	0.993989
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	3138.573
Std. Err. of Coef.	81.35767

Plot 1-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	1500	1500
2	2700	4200
3	2700	6900
4	2800	9700
5	2950	12650
6	2800	15450
7	2750	18200
8	2850	21050
9	2800	23850
10	2800	26650

Regression Output	
Constant	-965.909
Std Err of Y Est	395.2336
R Squared	0.998302
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	2741.364
Std. Err. of Coef.	37.68404

Plot 1-3

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	1550	1550
2	2200	3750
3	2750	6500
4	2750	9250
5	2750	12000
6	2750	14750
7	2750	17500
8	2750	20250
9	2700	22950
10	2750	25700

Regression Output	
Constant	-1031.82
Std Err of Y Est	440.7753
R Squared	0.997735
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	2646.364
Std. Err. of Coef.	42.02627

Site: Highway #115 Intensity: 16 cm/h August 4, 1990
Subsoil (Reconsolidated)

Plot 2-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	600	600
2	1250	1850
3	1650	3500
4	1600	5100
5	1750	6850
6	1700	8550
7	1850	10400
8	1750	12150
9	1700	13850
10	1550	15400

Regression Output	
Constant	-984.091
Std Err of Y Est	430.5593
R Squared	0.994251
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	1619.545
Std. Err. of Coef.	41.05222

Plot 2-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	100	100
2	650	750
3	1500	2250
4	1850	4100
5	2100	6200
6	2550	8750
7	2100	10850
8	2700	13550
9	2250	15800
10	3750	19550

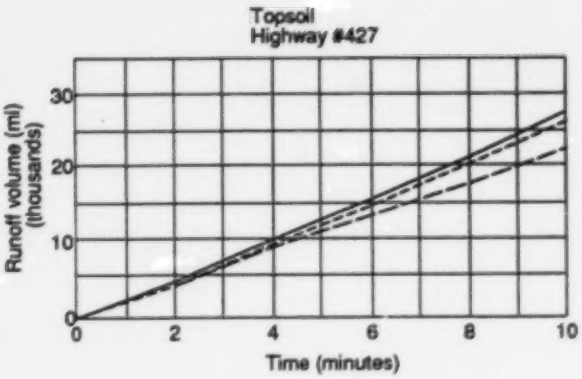
Regression Output	
Constant	-2590.91
Std Err of Y Est	1399.462
R Squared	0.961751
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	2007.273
Std. Err. of Coef.	133.4335

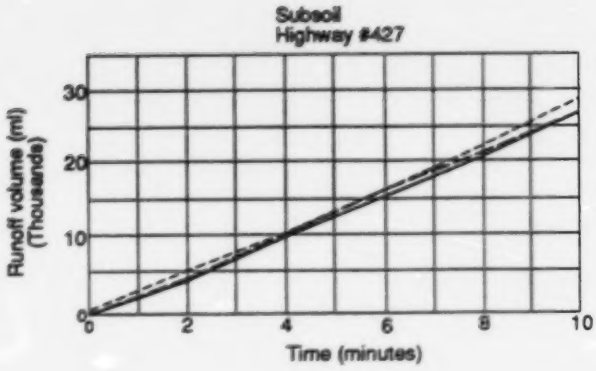
Plot 2-3

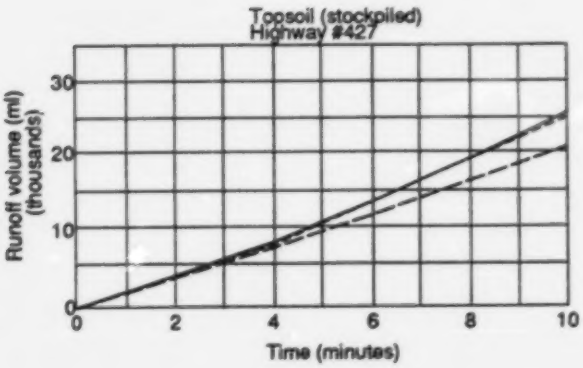
Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
1	300	300
2	2400	2700
3	2500	5200
4	2625	7825
5	2350	10175
6	2500	12675
7	2650	15325
8	2450	17775
9	2500	20275
10	2650	22925

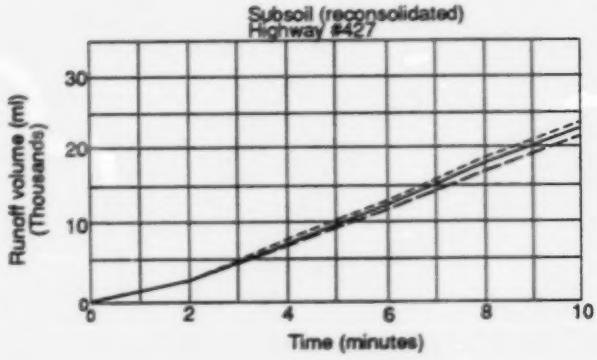
Regression Output	
Constant	-1568.18
Std Err of Y Est	637.1119
R Squared	0.994304
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	2407.727
Std. Err. of Coef.	60.74624

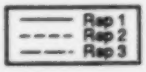
Appendix E/ Cumulative Volumes at Highway #427 Site











Site: Highway #427 **Intensity:** 16 cm/h **September 29, 1990**
Topsoil

Plot 3-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	3625	3625
4	5850	9475
6	5750	15225
8	6050	21275
10	6200	27475

Regression Output	
Constant	-1159.52
Std Err of Y Est	852.2676
R Squared	0.994738
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2801.071
Std. Err. of Coef.	101.8655

Plot 3-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	3000	3000
4	5250	8250
6	5750	14000
8	6200	20200
10	6300	26500

Regression Output	
Constant	-1569.05
Std Err of Y Est	1188.672
R Squared	0.989143
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2712.143
Std. Err. of Coef.	142.0734

Plot 3-3

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	3125	3125
4	4750	7875
6	4825	12700
8	4850	17550
10	5000	22550

Regression Output	
Constant	-855.952
Std Err of Y Est	624.352
R Squared	0.995799
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2297.857
Std. Err. of Coef.	74.62434

Site: Highway #427 **Intensity: 16 cm/h** **September 29, 1990**
Topsoil (Stockpiled)

Plot 4-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	3375	3375
4	5000	8375
6	5150	13525
8	5700	19225
10	6500	25725

Regression Output	
Constant	-1247.62
Std Err of Y Est	1026.098
R Squared	0.991113
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2590.357
Std. Err. of Coef.	122.6422

Plot 4-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	3300	3300
4	4675	7975
6	5150	13125
8	6275	19400
10	5500	24900

Regression Output	
Constant	-1260.71
Std Err of Y Est	1016.972
R Squared	0.990938
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2542.143
Std. Err. of Coef.	121.5514

Plot 4-3

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	2650	2650
4	4500	7150
6	4550	11700
8	4500	16200
10	4750	20950

Regression Output	
Constant	-935.714
Std Err of Y Est	681.8043
R Squared	0.994245
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2142.143
Std. Err. of Coef.	81.4912

Site: Highway #427 **Intensity:** 16 cm/h **September 29, 1990**
Subsoil

Plot 1-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	4425	4425
4	5600	10025
6	5550	15575
8	5625	21200
10	5875	27075

Regression Output	
Constant	-610.714
Std Err of Y Est	452.8186
R Squared	0.998433
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2732.143
Std. Err. of Coef.	54.12217

Plot 1-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	4075	4075
4	6250	10325
6	6350	16675
8	5975	22650
10	6150	28800

Regression Output	
Constant	-965.476
Std Err of Y Est	706.5215
R Squared	0.99672
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2943.929
Std. Err. of Coef.	84.44547

Plot 1-3

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	5200	5200
4	5500	10700
6	5375	16075
8	5500	21575
10	5500	27075

Regression Output	
Constant	-125
Std Err of Y Est	96.82458
R Squared	0.999927
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2712.5
Std. Err. of Coef.	11.57275

Site: Highway #427 Intensity: 16 cm/h September 29, 1990
Subsoil (Reconsolidated)

Plot 2-1

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	2500	2500
4	4750	7250
6	5125	12375
8	5175	17550
10	5000	22550

Regression Output	
Constant	359.5238
Std Err of Y Est	295.0383
R Squared	0.993023
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	841.4286
Std. Err. of Coef.	35.26383

Plot 2-2

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	2250	2250
4	5250	7500
6	5375	12875
8	5450	18325
10	5375	23700

Regression Output	
Constant	-1517.86
Std Err of Y Est	1101.12
R Squared	0.988668
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2458.571
Std. Err. of Coef.	131.609

Plot 2-3

Time (m)	Runoff (ml)	Cumulative Runoff (ml)
0	0	0
2	2725	2725
4	4225	6950
6	4750	11700
8	4750	16450
10	4675	21125

Regression Output	
Constant	-1000
Std Err of Y Est	741.0719
R Squared	0.993349
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	2165
Std. Err. of Coef.	88.57503

Appendix F/ Soil Losses from Simulated Rainfall Events

Sediment Concentration **August 4, 1990**

Site: **Highway # 115**

Sample	Average Soil (g/ml)	Runoff (ml)	Total Soil Loss (g/m2)	Soil Loss (T/Ha)	Average Soil Loss (g/m2)	Average Soil Loss (T/Ha)	Treatment
P1-1-10	0.377	30300	11422	114	6040	60	Subsoil
P1-2-10	0.131	26650	3482	35			
P1-3-10	0.125	25700	3216	32			
P2-1-10	0.148	15400	2285	23	2521	25	Subsoil reconsolidated
P2-2-10	0.165	19550	3232	32			
P2-3-10	0.089	22925	2046	20			
P4-1-10	0.042	13475	571	6	551	6	Topsoil
P4-2-10	0.040	13800	557	6			
P4-3-10	0.036	14600	526	5			
P3-1-10	0.062	16700	1041	10	1637	16	Topsoil stockpiled
P3-2-10	0.105	16650	1748	17			
P3-3-10	0.120	17650	2123	21			

Pipette Analysis **August 4, 1990**

Site: **Highway #115**

Sample	Filter (g)	Filter + Soil (g)	Soil (g/25 ml)	Average Soil (g/25 ml)	Treatment
P1-1-10	1.084	10.733	9.649	9.424	
P1-1-10A	1.082	10.281	9.199		
P1-2-10	1.084	4.340	3.256	3.267	Subsoil
P1-2-10A	1.083	4.360	3.277		
P1-3-10	1.079	4.251	3.172	3.129	
P1-3-10A	1.076	4.161	3.085		
P2-1-10	1.075	4.786	3.711	3.710	
P2-1-10A	1.075	4.783	3.708		
P2-2-10	1.083	5.272	4.189	4.134	Subsoil reconsolidated
P2-2-10A	1.081	5.159	4.078		
P2-3-10	1.077	3.340	2.263	2.232	
P2-3-10A	1.080	3.280	2.200		
P4-1-10	1.073	2.127	1.054	1.059	
P4-1-10A	1.082	2.146	1.064		
P4-2-10	1.076	2.164	1.088	1.009	Topsoil
P4-2-10A	1.073	2.003	0.930		
P4-3-10	1.084	1.931	0.847	0.901	
P4-3-10A	1.078	2.033	0.955		
P3-1-10	1.080	2.325	1.245	1.558	
P3-1-10A	1.079	2.950	1.871		
P3-2-10	1.076	3.700	2.624	2.624	Topsoil stockpiled
P3-2-10A	1.076	3.700	2.624		
P3-3-10	1.078	3.909	2.831	3.008	
P3-3-10A	1.075	4.259	3.184		

Sediment Concentration **September 29, 1990**

Site: **Highway # 427**

Sample	Average Soil (g/ml)	Runoff (ml)	Total Soil Loss (g/m2)	Soil Loss (T/Ha)	Average Soil Loss (g/m2)	Average Soil Loss (T/Ha)	Treatment
T11	0.027	27075	739	7	606	6	Subsoil
T12	0.019	28800	551	6			
T13	0.020	27075	529	5			
T21	0.024	22550	536	5	447	4	Subsoil reconsolidated
T22	0.021	23700	505	5			
T23	0.014	21125	300	3			
T31	0.062	27475	1709	17	1380	14	Topsoil
T32	0.050	26500	1314	13			
T33	0.050	22550	1116	11			
T41	0.070	25725	1789	18	1337	13	Topsoil stockpiled
T42	0.048	24900	1206	12			
T43	0.049	20950	1016	10			

Pipette Analysis **September 29, 1990**

Site: **Highway #427**

Sample	Filter (g)	Filter + Soil (g)	Soil (g/25 ml)	Average Soil (g/25 ml)	Treatment
T11	1.08	1.763	0.687	0.682	
T11A	1.08	1.760	0.677		
T12	1.07	1.656	0.584	0.478	Subsoil
T12A	1.07	1.446	0.373		
T13	1.08	1.550	0.475	0.489	
T13A	1.08	1.578	0.502		
T21	1.08	1.639	0.562	0.594	
T21A	1.08	1.703	0.626		
T22	1.08	1.595	0.515	0.533	Subsoil reconsolidated
T22A	1.08	1.627	0.550		
T23	1.08	1.426	0.349	0.354	
T23A	1.08	1.440	0.360		
T31	1.08	2.828	1.748	1.556	
T31A	1.08	2.444	1.363		
T32	1.08	2.179	1.100	1.240	Topsoil
T32A	1.08	2.459	1.380		
T33	1.08	2.288	1.209	1.238	
T33A	1.08	2.350	1.266		
T41	1.08	2.828	1.746	1.739	
T41A	1.08	2.816	1.732		
T42	1.08	2.301	1.223	1.211	Topsoil stockpiled
T42A	1.08	2.280	1.199		
T43	1.08	2.272	1.190	1.213	
T43A	1.08	2.316	1.236		